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(54) Liquid level sensor

(57) A liquid level sensor of the total internal reflection type, which is leak proof and not sensitive to pressure or temperature, comprises a plug 1 having a face 20 which when contacting a fluid will reflect or transmit light in dependence of the refraction characteristics of the fluid, a plug retaining member 32 with surface portions which retain the plug in the member against the action of excess pressure, a light source 4 and a reflected light receiver 6 both remote from the plug and light guides 9, 9′ for guiding light to and from the plug; preferably the components constituting a single cartridge.

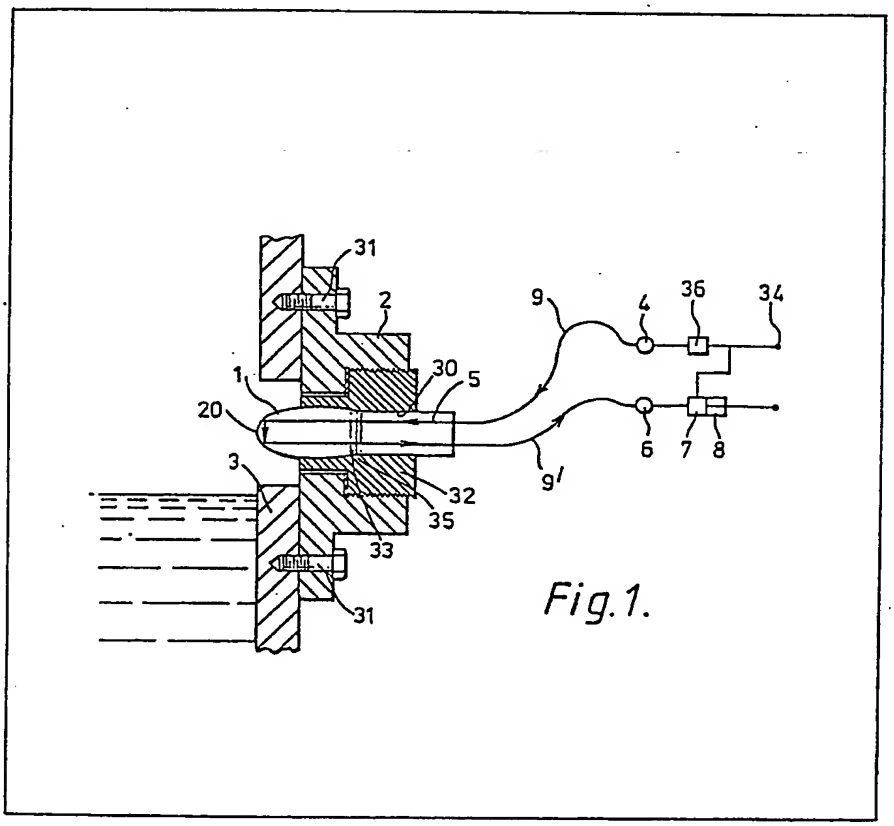

Fig.1.

The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

GB 2 036 326 A

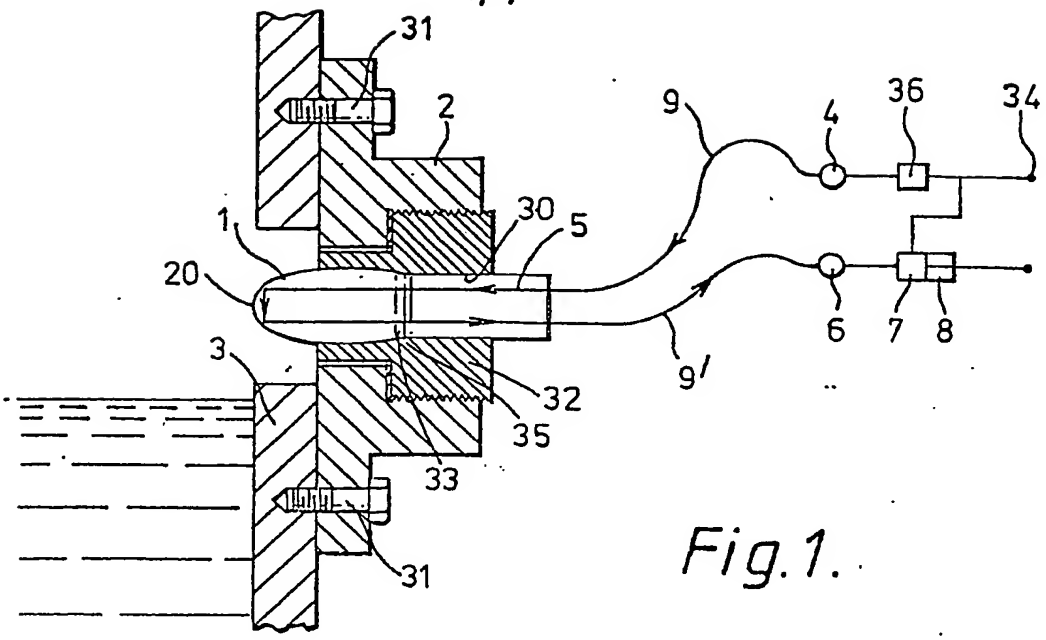

Fig. 1.

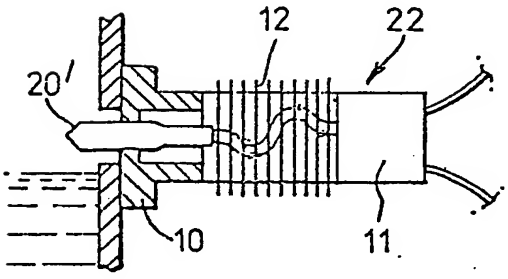

Fig. 2.

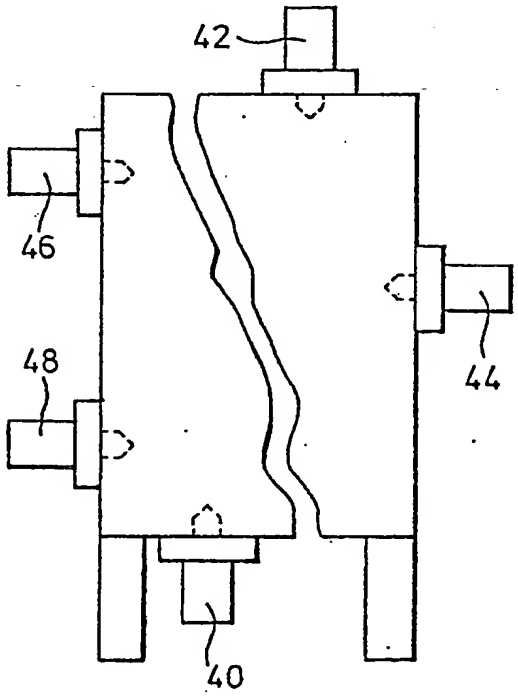

Fig. 3.

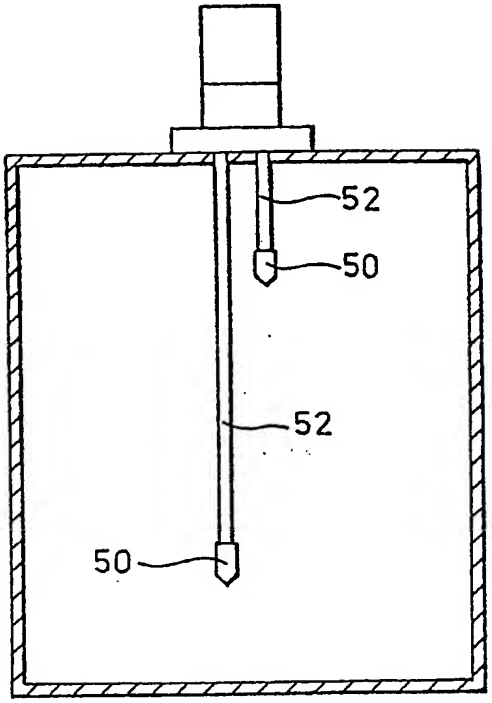

Fig. 4.

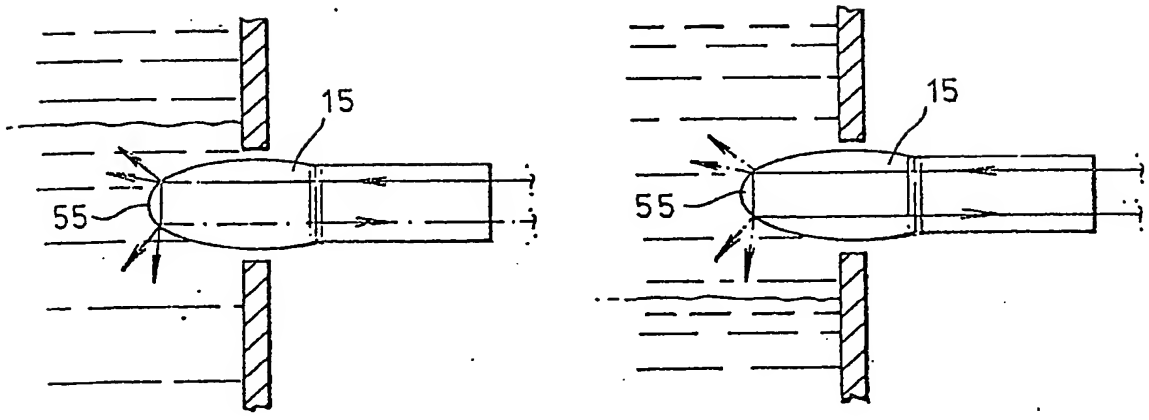

Fig. 5.

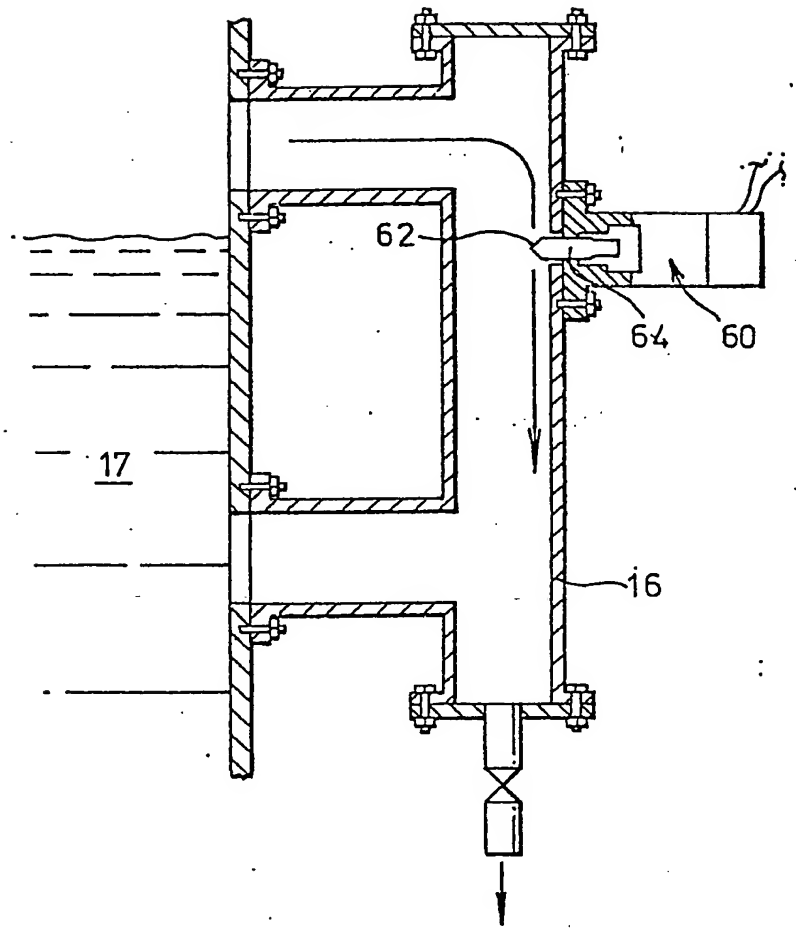

Fig. 6.

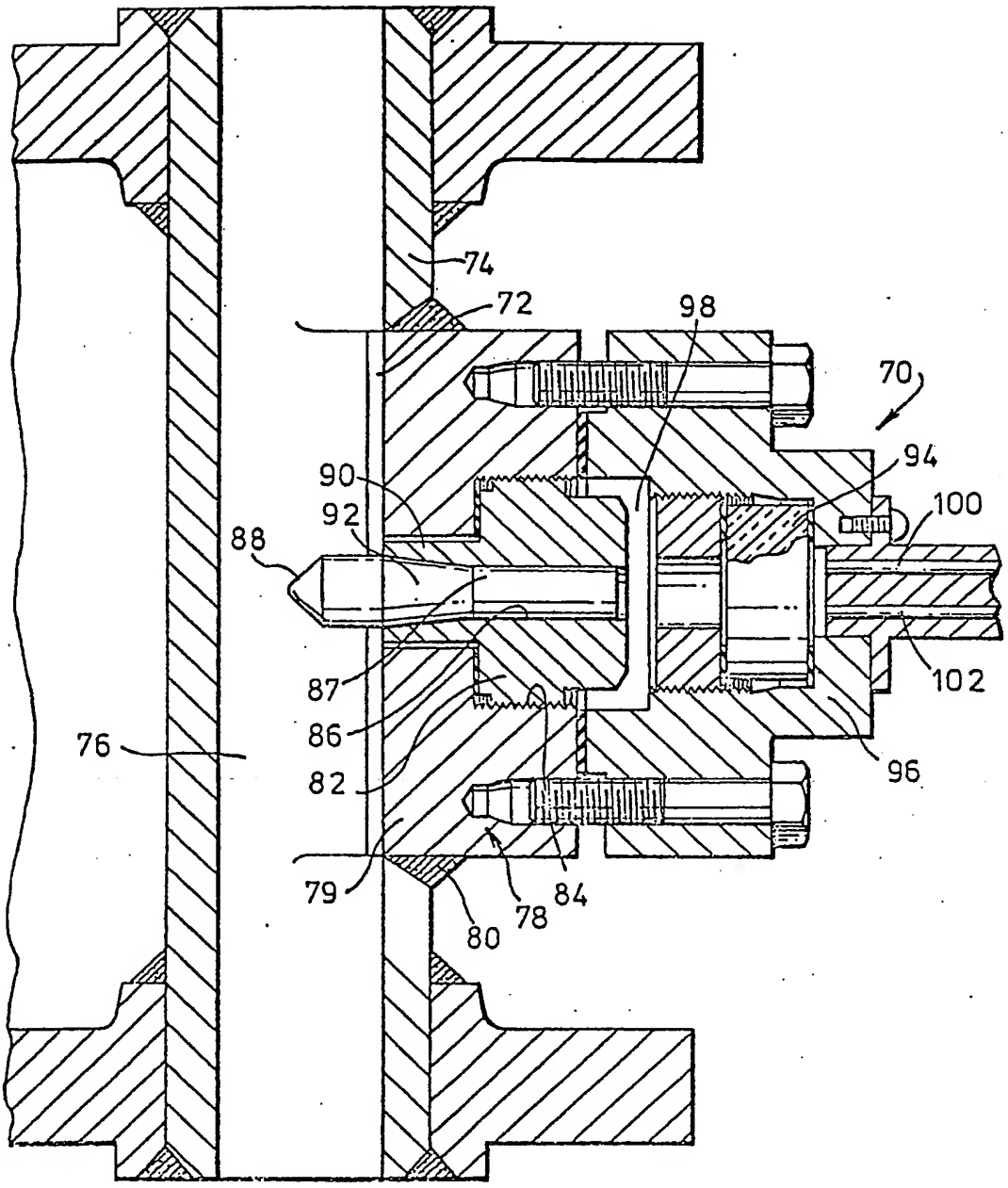

Fig. 7.

SPECIFICATION
Liquid level sensor

The present invention relates to a lqiuid level sensor capable of sensing when the liquid level in a container attains a predetermined height, the sensor being particularly useful for sensing the height of a liquid through the wall of a steel container.

Known liquid level sensors have included moving parts. For example, some known liquid level sensing devices make use of permanent magnets on either side of a steel container wall which move as a result of a contact of the liquid with the sensor, thus enabling actuation of a signal indicating that the predetermined liquid height had been reached. However, such moving parts may be subjected to particularly high pressures and temperatures which may cause distortion of the parts, thus giving misleading results.

As an alternative, sensors employing electrical connection through the steel wall have also been employed, but again these can be adversely influenced by the above mentioned extreme conditions.

Another type of liquid level sensor which has been adopted is the so called "optical dipstick", which makes use of certain known optical properties of a light transmitting plug provided with a face so positioned that it can come directly into contact with the liquid when the liquid reaches a predetermined height. Such devices operate by directing light from a source to the said face and arranging for any light reflected (but only reflected light) from the face to be detected by a light receiver, for example, a photoelectric cell. However, such optical dipsticks suffer from the disadvantage that the inherent thermal instability of the components (usually electronic) required for sensing the reflected light limit the reliability of such a device. Indeed both temperature and pressure would be hostile to such components. In addition, there is the serious danger that the plug could be blown out of position in the container wall thus rendering it inoperative, but more seriously thus allowing leakage of the fluid out of the container through the resultant opening in the wall.

The present invention provides an optical dipstick which does not suffer from the abovementioned disadvantages, these respectively disadvantages being overcome by enabling the reflected light receiver to be spaced remote from the light transmitting plug so as not to be subject to the adverse conditions of temperature and pressure which may obtain in the container and by providing means enabling the sensor to be readily secured to the wall or lid of the container so as to form an efficient fluid-tight seal preventing leakage of fluid through the opening in the wall or lid of the container in which the liquid level sensor is disposed.

The present invention provides a liquid level sensor including

a cartridge capable of sealing a passage through a wall of a container for a liquid medium and comprising a plug retaining member provided with a bore passing through the plug retaining member to enable transmission of light through the container wall and a light transmitting plug securely engaged within the bore and having a face capable of contacting the liquid medium when the liquid medium attains a predetermined height within the container, and being capable of reflecting or transmitting light in dependence of the refraction characteristics of the medium contacting the said surface,

the said plug retaining member including a surface portion in abutment with a surface portion of the light transmitting plug to define a stop capable of retaining the light transmitting plug in enagement within the bore of the plug retaining member against the action of excess pressure within the container tending to urge the light transmitting plug through the bore and out of engagement therewith,

a light source remote from the light transmitting plug and capable of emitting a predetermined quantity of light through the light transmitting plug to the said face thereof,

a light receiver remote from the light transmitting plug and capable of receiving and sensing only the light reflected from the said light reflecting or transmitting face thereby to sense contact of the said face with the liquid medium, and

first and second light guides capable of guiding, respectively, the light emitted from the light source to the light transmitting plug and the said light reflected from the said reflecting or transmitting face of the light transmitting plug to the light receiver remote therefrom.

A liquid level sensor embodying the invention can thus reduce the danger of leakage of fluid from the container wall through the aperture provided for installation of the liquid level sensor in two different ways. Thus (A), if the plug retaining member is constructed of a material, for example, the same material as that of the container, which can easily be secured e.g. by welding to the wall of the container, then it is a simple matter for the user merely to provide an aperture in the container wall (or lid) and secure the cartridge in position to efficiently seal the aperture, and (B) if a suitable adhesive is applied between the abutting surface portions of the plug retaining member and the light transmitting plug respectively, then the plug is secured within the bore of the plug retaining member, the surface portion of which defines a stop capable of retaining the light transmitting plug in engagement within the bore against the action of excess pressure within the container.

Two constructions of plug retaining member and light transmitting plug which provide the respective surface portions are as follows, namely,

(a) the bore of the plug retaining member is provided with a surface portion which tapers

inwardly away from the light reflecting or transmitting face of the light transmitting plug and abuts a corresponding surface portion of the light transmitting plug disposed within the bore so that, when the cartridge is disposed within the passage through the container wall, excess pressure within the container tends to urge the tapering surface portion of the light transmitting plug against the tapering surface portion of the bore, and

(b) the surface portion of the retaining member is defined by an end face thereof facing towards the light reflecting or transmitting face of the light transmitting plug and the surface portion of the light transmitting plug is defined by an annular surface thereof provided by a stepped portion of the light transmitting plug, and said annular surface of the light transmitting plug and end face of the plug retaining member abutting one another so that again, when the plug retaining member is disposed within the passage through the container wall, excess pressure within the container tends to urge the annular face of the stepped portion of the light transmitting plug against the end face of the plug retaining member, thus retaining the light transmitting plug within the bore of the plug retaining member.

A preferred liquid sensor embodying the invention takes the form of a single said cartridge including each of the plug retaining member, the light transmitting plug, the light source, the light receiver and the first and second light guides. Such a cartridge may be provided additionally with a temperature dissipating distance piece disposed between the light emitting plug and a unit comprising the light source and light receiver. The light guides may pass through the said distance piece.

In an especially preferred liquid level sensor embodying the invention, the plug retaining member and light emitting plug therein are surrounded by a housing defining a fluid-tight chamber, which housing includes light transmitting means, for example, a transparent shield spaced from the light transmitting plug and capable of transmitting to the light transmitting plug light from the light source via the first light guide, and, from the light transmitting plug, light reflected from the face to the light receiver, via the second light guide. The transparent element is preferably coaxial with the light transmitting plug. The liquid level sensor may additionally include a sensor capable of sensing leakage of fluid into the fluid-tight chamber.

Preferred embodiments of the invention will now be described with reference to the accompanying drawings wherein:—

Figure 1 is a schematic illustration of a liquid level sensor embodying the invention secured to a wall of a container for sensing when a liquid reaches a predetermined height therein,

Figure 2 is a schematic illustration of a liquid level sensor in the form of a single cartridge,

Figure 3 shows various attitudes which a liquid level sensor embodying the invention may assume relative to a container,

Figure 4 schematically illustrates a single cartridge liquid level sensor embodying the invention and being provided with two light emitting plugs for sensing respective upper and lower levels of a liquid in a container,.

Figure 5 shows the light transmitting plug only of a liquid level sensor and illustrates its use for determining the level of an interface between two liquids of differing refractive index,

Figure 6 schematically illustrates the installation of a liquid level sensor in a separate chamber in communication with a container and

Figure 7 is a cross-sectional view of another embodiment of the invention in which the liquid level sensor includes a housing defining a fluid-tight chamber.

Figure 1 shows a liquid level sensor embodying the invention including a light transmitting plug 1 of transparent material (toughened glass is preferably used) disposed essentially within a bore 30 passing axially through a plug retaining member 32. The plug 1 can be secured within the bore 30 of the plug retaining member 32 by means of an adhesive known for securing glass to steel. The plug 1 and the wall of the bore 30 of the plug retaining member 32 are provided with respective frusto-conical portions 33, 35 defining corresponding tapering surfaces abutting one another. An excess pressure in the container 3 thus urges the surface of frusto-conical portion 33 of the plug 1 towards the surface of frusto-conical portion 35 of the plug retaining member 32, which latter surface 35 serves to retain the plug 1 in the bore 30 against the action of the excess pressure preventing the plug 1 from being blown out of engagement with the plug retaining member 32. The plug retaining member 32 is disposed in a housing 2 securely attached, for example, by bolts 31, at a chosen position to a wall or lid of a container for a liquid at which chosen position there is an aperture sealed by the liquid level sensor. The housing 2 can be made of a material e.g. steel, which is the same as that of the container 3 and which is capable of withstanding any pressures likely to obtain in the container 3. It can then be readily welded and/or bolted to the wall of the container 3. Similarly, the plug retaining member 32 may be of the same material as the housing 2 and may be merely welded in position in the housing 2. In this construction, a power supply applied to the terminal 34 feeds, via a power source stabilizer 36, a stablized rectified voltage to a controlled light source 4 optimised in the infra-red waveband and this supplies a light signal 5 to a first light guide 9 which in turn guides the light of the light transmitting plug 1 (alternative energy sources can be used together with the light signals optimised to other areas of the spectrum to achieve a similar effect). The light passes through the plug 1 in a direction generally parallel to the longitudinal axis thereof until the light strikes a multi-angled face 20 of the plug with which the liquid comes into contact when it reaches a predetermined height. If liquid is not present then

the light will be reflected at least twice by the said multi-angled face 20 as shown in Figure 1 and will return along a similar path through the plug and be guided by a second light guide 9' to a reflected light receiver in the form of a light sensitive cell 6, which light sensitive cell 6 will generate a microcurrent which is transferred to an amplifying device 7 and on to a change-over switching circuit 8. This may be operated either to enable control, of the liquid level or to send out an alarm signal when the liquid level reaches a predetermined height.

If, however, the multi-angled face 20 of the plug 1 is in the contact with the liquid, then the light will largely penetrate the face, this being because the interface of the plug and the liquid substantially reduces the reflecting ability of the multi-angled face 20 of the plug 1.

In such a construction of liquid level sensor, the light sensitive cell 6 (which may, for example, be a silicone photodiode receiver) is disposed remote from the container 3 and the electronic components thereof are thus not subject to the conditions of temperature and pressure in the container.

The first and second light guides 9, 9' may be rigid or flexible but are preferably flexible optical glass fibre light guides.

Using such a liquid level sensor, the transparent plug 1 and housing 2 may be located in particularly hazardous environments (such as those of the combustible or explosive nature) without the electronic components of the light sensitive cell 6 being affected.

Since the face 20 is multi-angled, the sensor can be employed to sense when an interface between two immisible liquids of different specific gravity and refractive index attains a predetermined level as later described. In addition, such plugs have no rapid changes in their cross-section and are therefore more stable, i.e. less likely to be damaged by excess pressure or impinging particles.

Figure 2 shows a preferred construction of liquid level sensor which takes the form of a single integral cartridge 22. The cartridge 22 includes two sub-units 10 and 11 spaced apart by a temperature dissipating distance piece 12. The sub-unit 10 disposed adjacent the container 3 and influenced by the conditions therein consists of the transparent plug and housing, while the second sub-unit 11 spaced from the container 3 consists of the light source and light signal activated circuitry. Where the liquid level sensor is to be used only for sensing the height of the liquid and not for sensing the height of an interface between two liquids, the face 20' of the plug need only be provided with one angle as shown in Figure 2, the construction thus being simplified.

Figure 3 shows possible alternative positions for mounting a liquid level sensor embodying the invention. Thus, for determining when the liquid level is approaching the base of a container, the cartridge can be disposed generally vertically and so as to protrude upwardly from the bottom of the container (cartridge 40) or alternatively when the complete filling of the container is t be sensed, the cartridge, can be disposed generally vertically and protruding downwardly from the lid of the container (cartridge 42). Where a predetermined height between top and bottom of the container is to be sensed, then the cartridge is conveniently mounted on a vertical wall of the container so as to be disposed generally horizontally and protrude inwardly from the wall (cartridge 44).

For sensing upper and lower levels of a liquid in a container, two cartridges may be disposed on a vertical wall of the container and spaced apart from one another (cartridges 46, 48 of Figure 3). Alternatively, such upper and lower levels can be sensed by employing a single cartridge containing two transparent plugs 50, as shown in Figure 4. Such a construction includes a pair of sheathed light guides 52 extending generally vertically into the container to the respective transparent plugs 50 disposed at different vertical levels in the container. The transparent plugs 50 have respective energy sources and circuitry associated therewith, but the entire liquid level sensing device can be provided as a single cartridge for controlling the height of a liquid at predetermined upper and lower levels.

Figure 5 illustrates how a transparent plug 15 provided with a multi-angled face 55 can be employed to sense when an interface between two imiscible fluids of differing specific gravity and refractive index reaches a predetermined height. The angular variation of the multi-angled face 55 is so designed that when no liquid is contacting the face, the light signal is substantially reflected in the plug 15 and returned to the receiver essentially as previously described. When a liquid of low refractive index contacts the plug then a controlled partial reflection occurs, whereas when a liquid of high specific gravity contacts the plug the light signal is substantially transmitted. The light signal receiver in this construction can be adjusted to be sensitive to the partially reflected light signal and will differentiate between a lower intensity signal and no signal. In this manner, an interface between two liquids of dissimilar reflective characteristics can be determined.

In a particularly preferred plug of this nature, the face 55 is essentially parabolic. In such a case, the light beam leaves the plug 15 when its angle of incidence is less than the critical angle. Since the parabola presents a variable angle to the plug, a parallel light beam will arrive at the glass-fluid boundary with a varying angle of incidence. Thus a critical angle will exist for all fluids (provided that their refractive index is less than that of the glass) and depending upon their refractive index a greater or lesser percentage of the light beam will be transmitted. The electronic circuitry of the light sensitive cell must then be capable of detecting the relatively small changes in the reflected light.

Particularly where the level of an interface between two liquids is to be sensed (and even if only the height of a single liquid is to be sensed) it is preferred to employ a light source which will

emit modulated light. In such cases, the light sensitive cell can be such as to determine both intensity and number of pulses of modulated light and to thereby disregard spurious signals received from extraneous light. In addition, where corrosion or deposition alters the nature of the surface, again the slight deteriorating light reflective properties of the face of the plug are detected by light sensitive cells.

Referring now to Figure 6, this shows a cartridge 60 essentially as described with reference to Figure 2, but mounted in an auxiliary chamber 16 connected to, but separate from, a parent container 17. In this construction it is possible to vent the auxiliary chamber 16 to atmosphere or to a safe disposal area so using the scouring effect of the rapidly moving fluid to clean the angled face 62 of the transparent plug 64. Alternatively, the auxiliary chamber 16 can be isolated from the parent container and the plug cleaned independently either in position or after having been removed from the auxiliary chamber 16.

Referring now to Figure 7, this shows in longitudinal cross section, a liquid level sensor cartridge 70 disposed so as to seal an aperture 72 provided in a wall 74 of an auxiliary chamber 76 such as that shown in Figure 6. In this embodiment, the cartridge 70 includes a housing 78 including a sealing portion 79 securely welded within the aperture 72 by a weld 80. The housing 78 houses a plug retaining member 82 which sits in a stepped bore 84 of sealing portion 79 of the housing 78 and is welded therein. The plug retaining member 82 has a bore 86 passing therethrough in which sits a light transmitting plug 87. The light transmitting plug 87 can be secured within the bore 86 by a suitable adhesive for bonding glass to steel. The light-transmitting plug 87 is provided with an angular face 88 disposed within the chamber 76 and capable of contacting fluid in the chamber 76 when it reaches a predetermined height. The wall of the bore 86 of the plug retaining member 82 and the light transmitting plug 87 are provided with respective frusto-conical portions 90, 92 defining corresponding tapering surfaces abutting one another so that when excess pressure obtains in the chamber 76, the tapering surface of the frusto-conical portion 92 of the light transmitting plug 87 is urged more firmly against the corresponding tapering surface of the frusto-conical portion 90 of the plug retaining member 82 which thus prevents blowout of the light transmitting plug 87 from engagement with the bore 86 in the plug retaining member 82. In the embodiment shown in Figure 7, the housing 78 includes a transparent shield 94. The transparent shield 94 is held in spaced relation and coaxial with the plug 86 by means of a cap 96 securely sealed and bolted to sealing portion 79 of the housing 78. The sealing portion 79, cap 96 and transparent shield 94 of the housing thus together define a fluid-tight chamber 98 between the light transmitting plug 87 held by the retaining member 82 and the transparent shield 94. Light from a light guide 100 passes through the transparent shield 94, thence through chamber 98 and to the light transmitting plug 87. This light is reflected or transmitted by the angular face 88 of the plug in depdence of the refractive index of the medium in contact therewith. Nonabsorbed light is reflected twice by angular surface 88 and then returned through the light transmitting plug 87 along a path generally parallel to the incident light through the plug 86, chamber 98 and transparent shield 94. The reflected light is guided by light guide 102 to a light receiver (not shown).

Should leakage occur as a result of damage to the light transmitting plug 87 (e.g. fracture of the glass by corrosion or by solid particles in the fluid channel impinging thereon), then the fluid escaping will be merely held in the fluid-tight chamber 98 and will not escape through to the atmosphere, this being an invaluable safety factor. The sensor cartridge 70 may be provided with means capable of sensing such a leakage by, for example, sensing an increase in pressure in the fluid-tight chamber 98 or merely sensing the presence of the fluid itself in the fluid-tight chamber 98.

As shown in Figure 7 the liquid level sensor conveniently takes the form of a single cartridge.

CLAIMS

1. A liquid level sensor including

A cartridge capable of sealing a passage through a wall of a container for a liquid medium and comprising a plug retaining member provided with a bore passing through the plug retaining member to enable transmission of light through the container wall and a light transmitting plug securely engaged within the bore and having a face capable of contacting the liquid medium when the liquid medium attains a predetermined height within the container and being capable of reflecting or transmitting light in dependence of the refraction characteristics of the medium contacting the said surface,

the said plug retaining member including a surface portion in abutment with a surface portion of the light transmitting plug to define a stop capable of retaining the light transmitting plug in engagement within the bore of the plug retaining member against the action of excess pressure within the container tending to urge the light transmitting plug through the bore and out of engagement therewith,

a light source remote from the light transmitting plug and capable of emitting a predetermined quantity of light through the light transmitting plug to the said face thereof,

a light receiver remote from the light transmitting plug and capable of receiving and sensing only the light reflected from the said light reflecting or transmitting face thereby to sense contact of the said face with the liquid medium, and

first and second light guides capable of guiding, respectively, the light emitted from the light

source to the light transmitting plug and the said light reflected fr m the said light reflecting or transmitting face of the light transmitting plug to the light receiver remote therefrom.

2. A liquid level sensor according to claim 1 wherein the said surface portion of the plug retaining member and the said surface portion of the light transmitting plug in abutment therewith consist of respective surfaces disposed within the bore of the plug retaining member, which respective surfaces taper inwardly away from the said light reflecting or transmitting face of the light transmitting plug so that, when the cartridge is disposed in the passage through the container wall, excess pressure within the container tends to urge the said tapering surface portion of the light transmitting plug against the said tapering surface portion of the plug retaining member to thereby retain the said light transmitting plug within the bore of the plug retaining member.

3. A liquid level sensor according to claim 1 wherein the surface portion of the said retaining member is defined by an end face thereof facing towards the said light reflecting or transmitting face of the light transmitting plug and the said surface portion of the light transmitting plug is defined by an annular surface provided by a stepped portion of the light transmitting plug, which said annular surface is capable of abutment with the said end face of the plug retaining member so that when the plug retaining member is disposed within the passage through the container wall, excess pressure within the container tends to urge the said annular surface of the stepped portion of the light transmitting plug against the said end face of the plug retaining member to thereby retain the said light transmitting plug within the bore of the plug retaining member.

4. A liquid level sensor according to any one of the preceding claims wherein the said cartridge further includes the said light source, the said light receiver and the said first and second light guides so that the said liquid level sensor takes the form of a single said cartridge.

5. A liquid level sensor according to claim 4 wherein the said cartridge additionally includes a temperature dissipating distance piece disposed between the light emitting plug and each of the said light source and the said light receiver.

6. A liquid level sensor according to claim 4 or claim 5 wherein the said plug retaining member is provided with two said bores and two said light transmitting plugs one securely engaged within each respective bore, the two said light transmitting plugs having respective said faces spaced from one another and capable of contacting the liquid medium when the liquid medium attains a respective predetermined height.

7. A liquid level sensor according to any one of the preceding claims which further includes a housing defining a fluid-tight chamber surrounding the plug retaining member, the housing including light transmitting means spaced from the light transmitting plug and capable of transmitting

(a) light from a first light guide to the light transmitting plug and

(b) light reflected from a said face of the said light transmitting plug to the second light guide.

8. A liquid level sensor according to claim 7 wherein the light transmitting means is a transparent shield coaxial with the light transmitting plug.

9. A liquid level sensor according to claim 7 or claim 8 which further includes a sensor for sensing leakage of the fluid from the container into the fluid-tight chamber.

10. A liquid level sensor according to claim 9 wherein the sensor senses excess pressure in the fluid-tight chamber caused by the leakage of fluid from the container into the fluid-tight chamber.

11. A liquid level sensor according to any one of claims 7 to 10 wherein the cartridge further includes the said light source, the said light receiver, the said first and second light guides, the said housing and the light transmitting means so that the liquid level sensor takes the form of a single said cartridge.

12. A liquid level sensor according to any one of the preceding claims wherein the light source is capable of emitting modulated light.

13. A liquid level sensor according to any one of the preceding claims wherein the said face of the light transmitting plug is angular so that light reflected thereby and received by the light receiver has been reflected by the said face at least twice.

14. A liquid level sensor according to claim 13 wherein the said face of the light transmitting plug is multi-angled such that the light from the light source is reflected a predetermined number of times in dependence upon the refraction characteristics of the medium contacting the said face, the said liquid level sensor thereby being capable of sensing when the interface between the two fluids of different respective refraction characteristics attains a predetermined height in the container.

15. A liquid level sensor according to claim 14 wherein the multi-angled surface is essentially parabolic.

16. A liquid level sensor according to any one of the preceding claims substantially as herein described and illustrated with reference to the accompanying drawings.

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